A63-1128-8,000-L180

TEXAS AGRICULTURAL EXPERIMENT STATION

A. B. CONNER, DIRECTOR
COLLEGE STATION, BRAZOS COUNTY, TEXAS

BULLETIN NO. 389 NOVEMBER, 1928

DIVISION OF PLANT PATHOLOGY AND PHYSIOLOGY

Relation of Cotton Root Rot and Fusarium Wilt to the Acidity and Alkalinity of the Soil

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†As of November 1, 1928. *Dean, School of Veterinary Medicine.
**In cooperation with U. S. Department of Agriculture.
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SYNOPSIS

Root rot of cotton, caused by the fungus PHYMATOTRICHUM OMNIVORUM, is the most destructive disease of cotton in Texas. It is especially serious in the "black lands," where the heavy soils usually contain much lime. The present study was planned to determine whether the distribution of the disease in Texas is actually correlated with differences in the acidity or alkalinity of the soil.

Laboratory studies of the growth of the fungus on culture media showed that it grew best at about the neutral point, pH 7.0, and that it would not grow so well in more acid or in more alkaline media.

Cotton fields in 16 counties of Texas were examined, and the acidity or alkalinity of the soil studied in relation to the presence of cotton root rot and also of Fusarium wilt. Root rot was found in acid soils (pH 5.5—6.4) as well as in neutral (pH 6.5—7.4) and alkaline soils (pH 7.5—9.0). However, in the alkaline and neutral soils the percentage of fields in which the disease was present was twice that in the acid soils, and root rot was also much more destructive in these fields than when it was found in acid soils. Fusarium wilt, on the contrary, was much more common on the acid soils.

Hence it is probable that the differences in the distribution of these two important cotton diseases can be explained as due in part to differences in soil acidity.

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RELATION OF COTTON ROOT ROT AND FUSARIUM WILT TO THE ACIDITY AND ALKALINITY OF THE SOIL

J. J. TAUBENHAUS, WALTER N. EZEKIEL, AND D. T. KILLOUGH*

The relation of acidity and alkalinity of the soil to the growth of plant pathogens and to the destructiveness of plant diseases induced by them has been extensively investigated during recent years. With certain diseases, such as potato scab, this relation has offered means of practical control in the field. Two distinct aspects are included in such studies: first, the influence of the acidity of the soil and of artificial culture media on the growth of the pathogen; and second, the possibility of utilizing such information for practical control measures under field conditions.

The intensity of the acidity or alkalinity of the soil as well as of solutions is measured chemically by determining the hydrogen ion concentration, which is expressed in units known as pH values. Neutrality is represented by pH 7.0; the acidity becomes more intense as pH values become lower than 7.0; and the alkalinity becomes more intense as pH values become higher than 7.0. A pH of 5.0 is ten times as acid as one of 6.0; similarly pH 4.0 is ten times as acid as pH 5.0.

The present work has been chiefly to determine the relation of the hydrogen ion concentration to the growth of *Phymatotrichum omnivorum* (Shear) Duggar, the fungus which causes root rot of cotton and many other plants. Studies were made under laboratory conditions to determine the pH range of the organism in pure culture. A field survey was then conducted in which cotton fields in different parts of Texas were examined and soil samples collected. The pH and basicity of these samples were determined and studied in relation to the occurrence of root rot and also of Fusarium wilt in the fields.

Experiments are now under way to find out whether the root rot disease may be controlled by changing the acidity or alkalinity of the soil to certain degrees harmful to the causal organism but without effect on the host. The results of this work will appear in later publications.

HISTORICAL

Only a few of the many studies relating plant diseases with the hydrogen ion concentration of substrata need be mentioned. Gillespie and Hurst (7) and Martin (9) found a definite relation between the

*The writers wish to acknowledge their indebtedness to Dr. G. S. Fraps for his advice and criticism during the progress of this work and his supervision of the chemical phases of it; to Mr. E. C. Carlyle for making the pH and basicity determinations of the soil samples; and to Mr. W. T. Carter and Dr. L. J. Pessin for assistance in the collection of some soil samples.

hydrogen ion concentration of the soil and the prevalence of potato scab in the field. Potato scab was seldom found on acid soils with a pH of 5.2 or less, whereas it was common on less acid soils. As a result of these studies, the New Jersey Agricultural Experiment Station is now recommending for New Jersey soils the application of sulphur for the control of potato scab. In working with tobacco blight (*Bacterium solanacearum*) Arrhenius (2) found that the causal organism is serious only in acid soils, and is seldom of any consequence in neutral or in alkaline soils. Similarly, the work of Johnson and Hartman (8), and of Anderson et al. (1) has shown that black root rot of tobacco is unimportant in an acid soil of pH 5.6, but increases in seriousness with corresponding increases of soil alkalinity. Chupp (3) has shown that with club root of cabbage, the disease is most virulent in soil with a pH value of 6.0, while infection practically ceases at a pH of 7.2 to 7.4. Progressive cabbage growers have for many years controlled club root by the application of lime to the soil. Scott (11) found that *Fusarium lycopersici,* the organism that causes tomato wilt, grew best in culture media of pH 4.5 to 5.5, and suggested that soil of appropriate alkalinity might aid in controlling the disease.

There appears to be no information in the literature on the relation of cotton root rot to acidity of the soil or of culture media. With regard to cotton wilt, caused by *Fusarium vasinfectum* Atk., more is known. Neal (10) found recently that this fungus grew better in culture media at pH 3.0 to 5.5 than in more nearly neutral or alkaline media, with the maximum growth in a strongly acid solution at pH 3.5. Fahmy (4), however, working with the Fusarium wilt in Egypt, found it abundant in experimental plots in which the soil was slightly alkaline, between 7.5 and 8.5, and mentions also that the disease was more destructive in heavy soil than in the lighter, sandy soils.

GROWTH OF PHYMATOTRICHUM OMNIVORUM AS AFFECTED BY THE HYDROGEN ION CONCENTRATION OF ARTIFICIAL MEDIA

Methods

A pure culture of *Phymatotrichum omnivorum* was isolated from a cotton plant, recently wilted by root rot, from a field of Houston clay soil at Substation No. 5 near Temple.

The organism was grown in 200 c.c. Erlenmeyer flasks, in oatmeal broth made of 10 grams of ordinary oatmeal and one liter of distilled water autoclaved 30 minutes at 10 pounds pressure, strained, and sterilized for 20 minutes at 15 pounds pressure. Amounts of acid or alkali previously determined as necessary to provide media of the desired pH were placed in 30 c.c. test tubes and sterilized separately for 15 minutes at 15 pounds pressure. Under aseptic conditions in the culture room, the contents of these test tubes were poured into Erlenmeyer flasks each of which contained 100 c.c. of oatmeal broth also previously autoclaved. With a sterilized pipette, 20 c.c. samples were then withdrawn from each

flask and stored in sterile tubes for hydrogen ion determination. The following day each flask was inoculated with small pieces of 10-day-old culture of *Phymatotrichum omnivorum* from oatmeal agar. Three flasks were used for each strength of acid or alkali.

The test tubes containing the treated media to be used for pH determination were allowed to stand for 24 hours to permit the liquid to become as clear as possible. Determinations of pH values were then made colorimetrically by the Gillespie (6) drop-ratio method. Growth

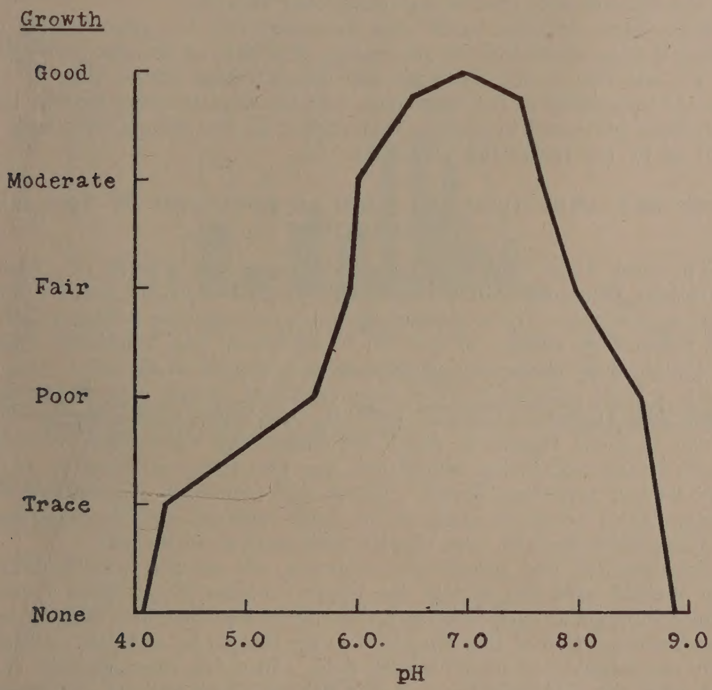

Figure 1.—Relation of the growth of *Phymatotrichum omnivorum* in artificial culture to the hydrogen ion concentration of the nutrient solution.

in the flasks was recorded after 6 weeks, and 20 c.c. of the clear portion of the media from each flask were then withdrawn by a sterile pipette for a final pH determination. Changes from the original acidity were found to be negligible.

Results

Acid media were secured by the addition of hydrochloric acid in one series, sulphuric acid in another, and acetic acid in a third. Sodium hydroxide was used for the single series with alkaline solutions. Growth

was almost precisely the same at the same pH readings with the three acids, and they will accordingly be considered together. The combined results, which are thus also nearly the same as those for each of the series, are shown graphically in Fig. 1.

Phymatotrichum omnivorum made its best growth at neutrality, pH 7.0. Growth was still nearly as good at pH 7.7, at 6.5, and at 6.0. At 5.9 and at 8.0 growth was definitely checked as compared to that in the neutral medium; and at 4.1 on the acid side of neutrality and 8.9 on the alkaline side growth was completely inhibited.

Since three different acids were employed and the same results secured, it is apparent that the prevention of growth of the root rot fungus at 4.1 was due to the hydrogen ion concentration rather than to the specific toxic effect of the other ions. In the alkaline range growth may have been prevented by specific toxic action by the sodium hydroxide as well as by the increasing alkalinity.

ROOT ROT AND FUSARIUM WILT AS AFFECTED BY THE SOIL REACTION

The work above had shown the relation of the growth of *Phymatotrichum omnivorum* in artificial culture to the pH of the solutions used as substrata. It was deemed desirable to determine further whether the presence or absence of root rot under actual field conditions might be explained by accompanying differences in the pH of the soil. Accordingly, a large number of fields were examined during May to October, 1925, and August to October, 1926, in 16 counties of the State. The survey included regions in which the disease was widespread, others in which it occurred in less abundance, and also some soil types in which root rot had never been found. Cotton wilt (caused by *Fusarium vasinfectum* Atk.) occurs in some of the fields included and the occurrence of this disease has also been studied with relation to the soil.

One hundred and seventy-six composite soil samples were collected. The method used was to take the upper 3 inches of soil from a dozen points throughout each field, mix thoroughly together, and select a representative portion of this composite as the sample for analysis. Usually only one sample was used for each field. In a few cases separate samples were obtained from the part of a field in which root rot was present and from the part in which it was absent.

The pH and basicity determinations (Fraps, 5, p. 12) of the soil were made by the Division of Chemistry of the Texas Agricultural Experiment Station. Determinations of pH were made colorimetrically. The basicity was determined by treating 10 gm. soil samples with 100 c.c. of 0.2 N nitric acid, filtering, and titrating with 0.1 N sodium hydroxide. The results are expressed as the percentage of basicity of the soils as calcium carbonate. It is to be noted that by the method of determination values above 10 per cent are not obtained, and this value in the tables therefore includes more basic soils.

Hydrogen Ion Concentration of the Soil and the Presence of Root Rot and Wilt

The data for the hydrogen ion concentration as related to the presence of root rot and wilt are given graphically in Figs. 2 and 3. In each case, the total number of fields in which the disease occurs is shown by the lower, black region of the chart. Even in these charts, without summation or averaging, a definite relation of the occurrence of root rot and

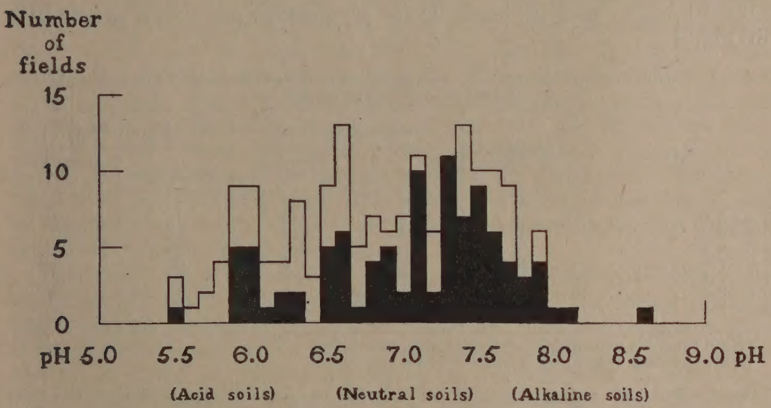

Figure 2.—Hydrogen ion concentration of the 176 soil samples, and the occurrence of root rot. The total number of samples with a given pH is shown by the upper line, and the number from fields with root rot by the lower, black portion.

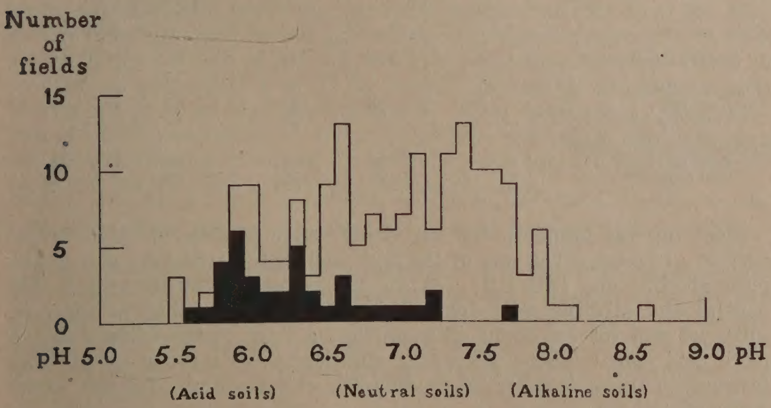

Figure 3.—Hydrogen ion concentration of the 176 soil samples, and the occurrence of Fusarium wilt. The total number of samples with a given pH is shown by the upper line, and the number from fields with Fusarium wilt by the lower, black portion.

Fusarium wilt to the pH of the soil is apparent. In Fig. 2, it will be noted that most of the root rot cases seem to fall to the right, or to the alkaline, side of neutrality, pH 7.0. With wilt, on the other hand (Fig. 3), the preponderance of cases is to the left, in the more acid soils.

This relation is more evident when the results are combined as in Table 1. Going down the columns of this table, that is, from acid to alkaline soils, the percentage of fields in which root rot was found steadily increases, while the percentage of fields in which Fusarium wilt occurred becomes steadily less. These percentages are shown graphically in Fig. 4.

Table 1.—Relation of the hydrogen ion concentration of the soil of cotton fields to the presence of root rot and Fusarium wilt.

pH	Number of fields	Number of fields with		Percentage of fields with	
		Root rot	Fusarium wilt	Root rot	Fusarium wilt
5.5—5.9	19	6	12	32	63
6.0—6.4	28	10	14	36	50
6.5—6.9	40	21	7	53	18
7.0—7.4	48	32	4	67	8
7.5—7.9	38	26	1	68	3
8.0—8.4	2	2	0	*100	*0
8.5—8.9	1	1	0	†100	†0

*Note that this percentage is based on only two fields.
†Note that this percentage is based on only one field.

Table 2.—Summary of the relation of the hydrogen ion concentration of the soil of cotton fields to the presence of root rot and Fusarium wilt.

	Total	Soil acid (pH 5.5-6.4)	Soil neutral or nearly neutral (pH 6.5-7.4)	Soil alkaline (pH 7.5-9.0)
All fields in the survey	176	47	88	41
Number of fields with:				
Root rot	98	16	53	29
Fusarium wilt	38	26	11	1
Percentage of fields with:				
Root rot	56	34	60	71
Fusarium wilt	22	55	13	2

Root rot was found in the entire pH range of soils included in the survey. It occurred in one of the most acid fields (pH 5.5) and in the most alkaline one (pH 8.6). While the percentage of root rot in the neutral and alkaline soils (note Table 2) was twice that in the acid soils, yet root rot was found in more than a third of the fields with the more acid soils. There was not a sufficiently wide range of pH differences in the soils surveyed to establish extreme limits for the occurrence of root rot.

Fusarium wilt occurred over a more limited part of the pH range of soils studied. No wilt was found in soils more alkaline than pH 7.7, and there were only four cases beyond 7.0. For the soils considered,

there is evidently a maximum pH limit between pH 7.6 and 8.0. The optimum and minimum for wilt are probably below the range included in this survey.

Hydrogen Ion Concentration and the Severity of Root Rot

The results were tabulated above with regard only to the presence or absence of the disease in a given field and without regard to its severity there. When we consider the prevalence of root rot in the individual fields, a slightly different relation is evident. The one case in which root rot was found in a soil with pH of 5.5 (see Fig. 1) was in a field with only a trace of the disease present. There were five cases of root rot at pH 5.8. Three of these were recorded as only a trace. All five of the fields at 6.0 had only a trace of root rot. All of the five cases from 6.1 to 6.5 were recorded as a trace. It is only with a pH of 6.9 that the disease appears to have been found in destructive abundance. Though in one field of this pH only a trace of infection was found, and in another about 1 per cent was estimated, there was in a third field an estimated infection of 95 per cent.

Thus while there was root rot in a total of 16 fields with soils more acid than pH 6.9, in 14 of these fields only a trace of the disease (usually less than 1 per cent) was present. Definite percentages of infection were not recorded for all of the fields in regions in which root rot is widespread, so that a complete summary of its abundance in the fields surveyed is not possible. However, of 10 fields with root rot, selected at random from those between pH 7.1 and 7.9, only two were recorded as "trace" or less than 1 per cent, five were between 10 and 50 per cent, and the other three from 50 to 75 per cent. More precise comparison is to be desired here, yet it appears quite safe to conclude from the data at hand that root rot is not only of more frequent occurrence on soils of pH 7.0 to 8.0 than of pH 5.5 to 6.9, but also that it is more often of destructive abundance when it is present on neutral or alkaline soils than when it is present on acid soils. This conclusion agrees with years of field observations by the senior author and others who have been acquainted with the effects of the root rot disease in the alkaline "black lands" of Texas and in the more acid sandy soils.

Basicity of the Soil and the Presence of Root Rot and Fusarium Wilt

The discussion above has been concerned with the relation of the degree of acidity or alkalinity of the soil to the distribution of the two diseases. The percentage of basicity is, on the other hand, not an indicator of the soil acidity but instead a measure of those basic constituents of the soil which are potential factors in affecting the present and future reaction of the soil. As such, one would expect the relation of the diseases to this criterion to be roughly similar to the relation to pH. This was found to be the case.

Summaries of the data as related to basicity of the soil are given in Tables 3 and 4. The proportion of fields affected by root rot increases

with the basicity while Fusarium wilt was found only in the less basic soil. As with the pH, the range for wilt is more definitely limited, at least for the fields of this survey, than was the range for root rot. Root rot occurred throughout the range of soil basicities, while no wilt was found in a soil more basic than 2.2 per cent, and only two cases in more basic soils than 0.8 per cent.

Percentages of fields in which root rot and Fusarium wilt occurred are shown graphically in Fig. 5. Note that the sudden fall in the root

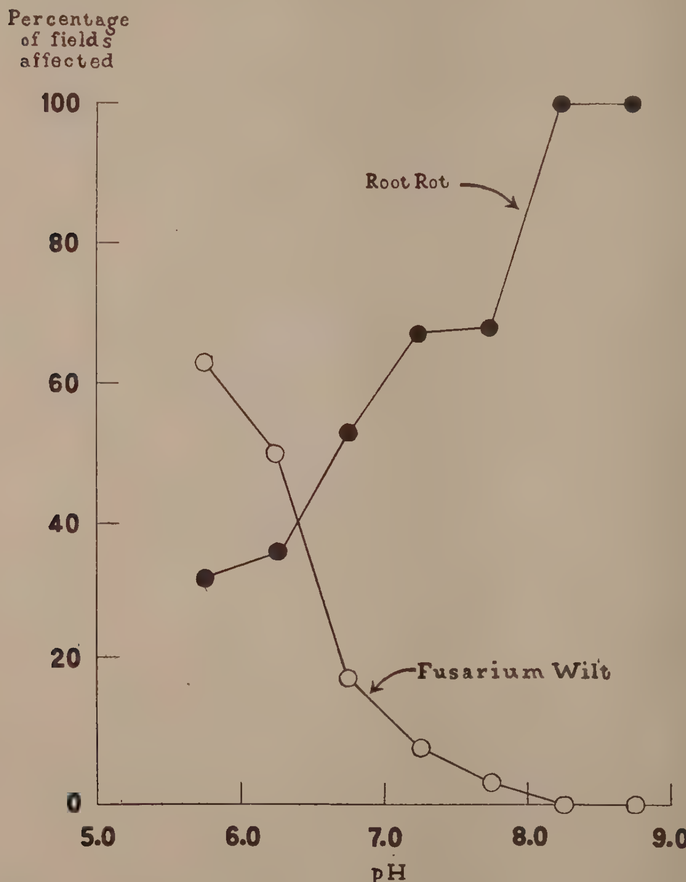

Figure 4.—Occurrence of root rot and Fusarium wilt with regard to the hydrogen ion concentration of the soil. (Data from Table 1.)

rot curve at 8 per cent basicity is of little significance, since there was only a single field in this group and the "0" root rot for the group applies to that one field.

Soil Reaction and the Distribution of Root Rot in Individual Fields

Root rot is often found only in particular areas in fields that are apparently of even soil type. Basicity and pH determinations for a few such fields are given in Table 5. It will be noted that the differences in soil acidity between parts of the fields in which root rot was found

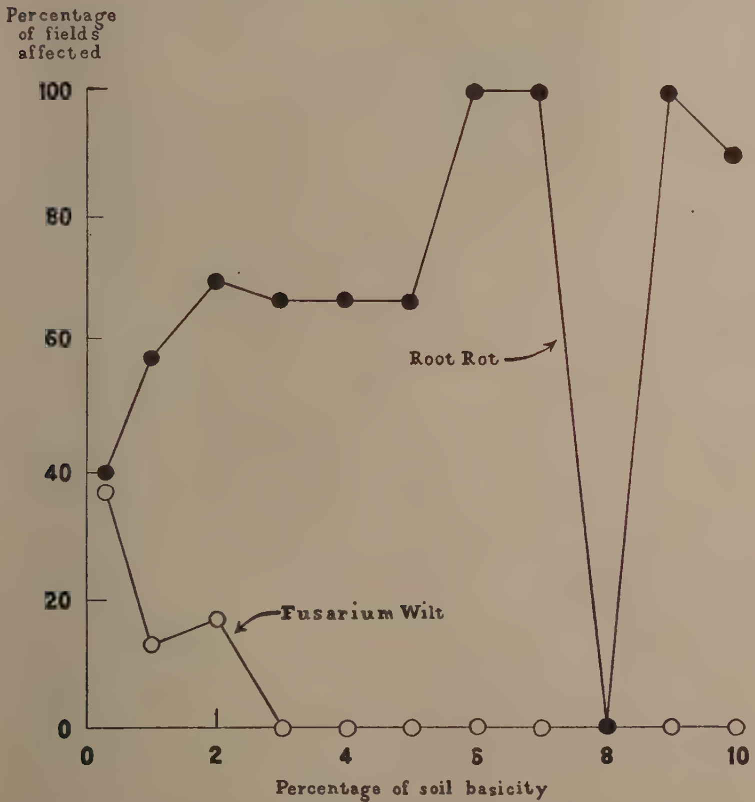

Figure 5.—Occurrence of root rot and Fusarium wilt with regard to the basicity of the soil. Note that the drop in the root rot curve at 8 per cent basicity is not considered significant since it was based on only one field (in which the soil was of that basicity). (Data from Table 3.)

Table 3.—Relation of the basicity of soils in cotton fields to the presence of root rot and Fusarium wilt.

Percentage of soil basicity	Number of fields	Number of fields with		Percentage of fields with	
		Root rot	Fusarium wilt	Root rot	Fusarium wilt
0.0— 0.4	82	33	30	40	37
0.5— 1.4	45	26	6	58	13
1.5— 2.4	12	9	2	75	17
2.5— 3.4	3	2	0	67	0
3.5— 4.4	6	4	0	67	0
4.5— 5.4	3	2	0	67	0
5.5— 6.4	1	1	0	*100	*0
6.5— 7.4	1	1	0	*100	*0
7.5— 8.4	1	0	0	*0	*0
8.5— 9.4	2	2	0	†100	†0
9.5—10.0	20	18	0	90	0

*Note that this percentage is based on only one field.
†Note that this percentage is based on only two fields.

Table 4.—Summary of the relation of the basicity of soils in cotton fields to the presence of root rot and Fusarium wilt.

	Total	Soil basicity (0–0.9)	Soil basicity (1.0–2.5)	Soil basicity (2.5–10.0)
All fields in the survey	176	114	25	37
Number of fields with:				
Root rot	98	48	20	30
Fusarium wilt	38	36	2	0
Percentage of fields with:				
Root rot	56	42	80	81
Fusarium wilt	22	32	8	0

and the parts in which it was absent are generally insignificant. Only in the second field, where a pH of 6.5 was found in the part with root rot as compared to 6.9 for the other part, is the difference appreciably greater than the probable experimental error. In three of the five fields, the parts free from root rot apparently had the slightly more acid soils, while in the other two fields the reverse was the case.

Further evidence on this point was obtained by a survey of the cotton fields on a single farm near College Station. The soil here was unusually varied and a number of different types occurred even in a small field. Comparing different types of soil in a given field, it was noted that root rot did not occur in the more acid types, Susquehanna gravelly fine sandy loam and Susquehanna fine sandy loam, in which the pH of the surface soil was 6.5-7.0; while it was found in the six other soil types that were at least slightly alkaline. To this extent, these results agree with comparisons between different farms and different regions. Distribution of the disease in a given soil type was, however, certainly not determined by the soil acidity alone. For example, in a field of Norfolk gravelly fine sand there was 80 per cent of root rot in part of the field where the surface soil was found to have a pH of 7.3, and no root rot where the pH was 7.4. In some Kirvin fine sandy loam there

was 98 per cent loss in one part of the field, 1 per cent loss in another, and no loss in a third place; while the soil was of the same pH, 7.1, in the three places.

Table 5.—Differences in soil acidity within fields as related to the presence of root rot. (Five fields in four different counties.)

Field	pH of Soil		Percentage of Soil Basicity	
	In Areas Where Root Rot was Present	In Areas Where Root Rot was Absent	In Areas Where Root Rot was Present	In Areas Where Root Rot was Absent
A....................	7.7	7.6	0.8	0.6
B....................	6.5	6.9	0.2	0.1
C....................	7.3	7.4	4.5	4.6
D....................	7.5	7.6	3.3	3.8
E....................	7.6	7.4	1.9	3.0

This is hardly surprising, for while soil acidity is a factor which can prevent the occurrence of root rot it is by no means the only one. Root rot may be checked to a certain extent by the acidity of surface soils more acid than about pH 6.5-7.0. But there are many other factors which may also prevent the occurrence or hinder the spread of the fungus even in soil of a favorable pH. We may mention here such factors as the effect of the prevalence of weed carriers on the success of hibernation, and the effect of soil moisture (12) on the spread of infection. With different soil types the occurrence of root rot is apparently affected to a great enough extent by differences in the soil reaction for the result to be evident even though these local factors are also active. With the comparatively slight differences in soil reaction between parts of a field of even soil type, on the other hand, the effect of the acidity differences if present seems to be completely obscured.

Reaction at Different Soil Depths, and Root Rot

The survey from which most of the results above were secured included samples of the surface soil only. Are differences in acidity of lower depths in the soil also of importance in relation to the distribution of root rot?

An idea of the differences in subsurface acidity, in soils with the same surface acidity, can be obtained from the following examples. Attention was called above to a field of Kirvin fine sandy loam near College Station. Root rot was very destructive in part of this field, where the pH of the surface soil was 7.1, and practically absent in another part where the pH was just the same. In the former case, however, the yellow sand from eight to twelve inches deep had a pH of 7.3 and the red clay below this of 7.1; while where root rot did not occur, the yellow sand at six to nine inches deep had a pH of 6.7 and the red clay subsoil, 6.4.

Compare, however, the distribution of root rot in the Norfolk gravelly fine sand. Root rot was abundant here in soil with a pH of 7.3, and

absent at pH 7.4. And the yellow sand subsoils, beginning six inches below the surface, gave pH readings of 7.3 in the first place, and 7.5 in the second. While in the Kirvin loam the subsurface acidity might have been the deciding factor in the distribution of root rot, this could scarcely have been true in the Norfolk soil.

Further study is planned to determine the effect of variations in subsurface acidity on the occurrence of root rot.

DISCUSSION

It has been shown above that cotton root rot was more abundant and also more destructive in fields with neutral or alkaline soils than in fields with acid soils. Fusarium wilt, on the contrary, was found to be restricted to the more acid soils.

With both diseases, these results secured from the field survey are in at least general accord with laboratory studies of the fungi causing the diseases. *Phymatotrichum omnivorum* was shown in the present paper to grow best in culture media adjusted to pH 7.0, or neutrality, and to be slightly inhibited in growth in only slightly acid media. In very acid media growth was completely inhibited. In the cultures growth was also less with slight alkalinity of the solution and ceased at a pH of 8.9. This is not in full agreement with the field results, since in the field root rot appeared to be more destructive in the more alkaline soils. The cause of this disagreement is perhaps the difference in the materials producing the alkalinity in the two cases, or the excretion by the roots of host plants of substances which produce pH conditions favorable for root rot even in soil that would otherwise be too alkaline. It should be noted that no fields were studied with soils as alkaline as pH 8.9, the point at which growth was prevented in artificial media.

There is better agreement of the distribution of wilt in soils of various acidities with the laboratory results of Neal (10) with *Fusarium vasinfectum.* In culture, this fungus grew much better at pH 5.5 than at 6.0 or 6.5, with further diminution of growth in alkaline media. Similarly, almost all the cases of wilt in the field were in soils that were at least slightly acid. The distribution of wilt appears to be more sharply limited on the alkaline side in the field than was the growth of the fungus in culture media.

Soil Acidity and the Distribution of Root Rot and Fusarium Wilt

These results are of interest in connection with the present distribution of the two diseases studied. Root rot has been widespread for years in the "black lands" and in other heavy soils of Texas but usually not in lighter soils. It is probable that this limitation of distribution was at least partly the result, either directly or indirectly, of the differences in the soil reaction.

As will be discussed in a forthcoming bulletin on the distribution of root rot, root rot occurs also in Oklahoma, New Mexico, Arizona, and

California, but has not been found in the other Southern States of the Cotton Belt, though climatic conditions are apparently favorable in many of them. The absence of root rot in these States may perhaps be explained by the acidity of the soils in these regions though absence of original infection may be the important factor.

Fusarium wilt of cotton, in common with the Fusarium wilts of many other plants, has been considered more destructive on sandy soils than on heavier soils. The present work furnishes an explanation of this observation in the fact that the lighter soils are generally acid and hence more suited to the disease.

It should be mentioned that this relation is evidently quite at variance with that of Fusarium wilt of cotton in Egypt, as studied by Fahmy (4, p. 55). Fahmy considers the Fusarium attacking cotton in Egypt to be distinct from the one common in this country, a conclusion which agrees with the fact that he finds wilt serious in plots with alkaline soil, pH 7.5 to 8.5, and occurring in the heavier soils. From this it would seem especially important to keep this Egyptian strain of the wilt organism from ever being imported into the American cotton regions, since it might prove destructive in soils in which the American strain has been of little importance.

Soil Acidity and the Control of Root Rot

Whether these results can be used as the basis for new methods of control in the field must be determined by further experiments. In this connection, it must be remembered that control of root rot by making the soil more acid, or control of wilt by making the soil alkaline, may be a slow process. The factor of soil reaction probably influences the presence or absence of these two organisms in the soil; but it may do this, particularly in soils near the limiting acidities, not so much by immediate destruction of the organisms in soils of unfavorable acidity as by gradual decrease each year in the proportions of infective materials that hibernate and are available in spring to start new spread of the diseases.

The fact that the two diseases, root rot and Fusarium wilt, occur respectively in alkaline and acid soils is to be considered in connection with such control measures. In fields in which both diseases occur, the addition of sulphur to make the soil more acid as an attempt to control root rot might increase losses from wilt, and similarly the addition of lime to produce an alkalinity unfavorable to wilt would doubtless favor increased loss from root rot. The most desirable soil acidity for such conditions would apparently be at about pH 6.5, considering only the results of the present survey.

SUMMARY

A study of *Phymatotrichum omnivorum* (Shear) Duggar, the fungus causing root rot of cotton and many other plants, on artificial media

showed that its maximum growth was at pH 7.0, and that its growth was completely inhibited at an acidity of pH 4.1 and at an alkalinity of pH 8.9.

Cotton fields in sixteen counties of Texas were examined in a field survey for cotton root rot and Fusarium wilt. Both the hydrogen ion concentration of the soil and the percentage of soil basicity were determined from soil samples from each field.

Root rot was found in 34 per cent of the fields with acid soils (pH 5.5-6.4), in 60 per cent of the fields with nearly neutral soils (pH 6.5-7.4), and in 71 per cent of the fields with alkaline soils (pH 7.5-9.0). Moreover, even when root rot did occur in the acid soils it was seldom of much significance, while in the neutral or alkaline soils root rot when present usually caused losses ranging from 10 to 100 per cent. Fusarium wilt, on the other hand, occurred in 55 per cent of the fields with acid soils, in 13 per cent of the fields with nearly neutral soils, and in only 2 per cent of the fields with alkaline soils.

Similarly, there was root rot in 42 per cent of the fields with a soil basicity of 0-0.9 per cent, in 80 per cent of fields with a basicity of 1.0-2.5 per cent, and in 81 per cent of fields with a basicity of 2.5-10.0 per cent, while Fusarium wilt was found in 32 per cent of the fields with the low basicity, in only 8 per cent of those of the second group, and in none of the fields with the most basic soils.

The distribution of the root rot and Fusarium wilt diseases in the cotton fields of this survey was thus correlated, in general, with the differences in the reaction of the soil. Root rot was more abundant in the alkaline soils and in the neutral soils than in acid soils, while the Fusarium wilt was more common in the acid soils. It seems probable that the present limitations in the distribution of these diseases in the parts of Texas that were not included in this survey and in the other cotton States may also be associated with such differences in the reaction of the soil. In this connection a potential danger to American cotton is pointed out in the presence in Egypt of a strain of Fusarium wilt which attacks cotton on alkaline soils also.

A few cases were studied in which root rot occurred only in particular areas in fields that were apparently of even soil type. It was found that the distribution of root rot in these fields was not associated with differences in the reaction of the soil. The disease is not necessarily present wherever soil conditions are favorable.

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